STORAGE PRESERVATION OF MACHINERY

by

Heinz P. Bloch

Senior Engineering Associate

Exxon Chemical Company

Baytown, Texas

Heinz P. Bloch is a Senior Engineering Associate with Exxon Chemical Company's Central Engineering Division, located in Baytown, Texas. He assists several plants in resolving machinery-related issues.

Mr. Bloch has held machinery-oriented staff and line positions with Exxon affiliates since 1965. His past assignments have included tours of duty at plant locations in the USA, Italy, Spain, England, The Netherlands and Japan. Troubleshooting and reliability improvement missions took him to affiliated companies and machinery manufacturing plants in 12 additional countries.

The extent and depth of Mr. Bloch's previous and continuing involvement in all aspects of machinery reliability improvement is indicated in over 40 technical society papers or similar publications. His books, entitled Improving Machinery Reliability *and co-authored texts on* Failure Analysis and Troubleshooting, Machinery Component Maintenance and Repair, *and* Major Process Equipment Maintenance and Repair *have been used for lectures and consulting assignments in the U.S., Indonesia, Kuwait, Pakistan, Suriname and other countries. He is presently working on a comprehensive text dealing with oil mist lubrication.*

Mr. Bloch graduated from the New Jersey Institute of Technology with B.S. and M.S. degrees in Mechanical Engineering in 1962. He was elected to three national honor societies, is a member of ASLE and ASME and maintains registration as a professional engineer in the State of New Jersey.

ABSTRACT

Storage preservation of machinery makes economic sense for as yet uncommissioned as well as temporarily deactivated ("mothballed") machinery. Storage preservation herein is divided into three main elements: turbomachinery rotor storage and preservation, preservation of inactive machinery by conventional coating or liquid fill methods, and preservation of inactive machinery by nitrogen or oil mist purge application. Guidelines are given on desirable properties or available preservatives. Typical cost data are presented for oil mist purge installations which have been effectively used in equipment storage facilities and on entire process units in the U.S. Gulf Coast area.

PRINCIPLES OF STORAGE PRESERVATION

Operating machinery must be protected from the elements. Painting, plating, sheltering, use of corrosion-resistant materials of construction and many other means are available to achieve the desired protection.

A similar set of protection requirements applies to as yet uncommissioned or temporarily deactivated equipment. The analysis discussed herein refers to that "inactive" machinery category. The means or procedures chosen for the preservation or corrosion inhibiting of fully assembled, but inactive process machinery will logically depend on the type of equipment, expected length of inactivity, geographic and environmental factors, and the amount of time allocated to restore the equipment to service.

The basic and primary requirement of storage preservation is exclusion of water from those metal parts which would form corrosion products ("rust") that could find their way into bearings and seals. A secondary requirement might be the exclusion of sand or similar abrasives from close-tolerance bearing or sealing surfaces. All or any of the storage preservation strategies must aim at satisfying these requirements.

For the sake of clarity, storage preservation will be divided into three main elements: turbomachinery rotor storage and preservation, preservation of inactive machinery by conventional coating or liquid fill methods, and preservation of inactive machinery by nitrogen or oil mist purge application.

TYPES OF PRESERVATIVES FOR ROTOR STORAGE AND CONVENTIONAL PROTECTION

Premium preservatives are manufactured to suit a particular requirement. Physical characteristics, application methods and life expectancies, etc., of products, identified as A through D, may differ, as shown in Table 1. This table represents an overview of interacting factors which will allow the specifying engineer to select the most appropriate preservative for a given situation. Note that Table 1 covers indoor as well as outdoor storage protection. The table does not, however, cover the lubricants or preservatives chosen for oil mist systems. These will be discussed in later sections.

Indoor Storage

The severity of indoor storage is a function of such factors as dampness, poor air circulation, widely fluctuating temperatures, or presence of corrosive fumes. If conditions are moderately severe, Product "C" will provide an adequate oily film and some abrasion resistance. It does not contain water-displacing or fingerprint-suppressing agents.

A second preservative, Product "B," has a grease-like consistency and leaves a thick film that will provide protection in the most severe environments. It can normally be applied by brush, but may have to be heated for application.

Outdoor Storage—Under Partial Shelter

If stored parts are sheltered from direct exposure to sun, rain, and snow, effective rust protection can be achieved with Product "B". This product forms a soft, thick, waxy coating. The surface of the coating gradually dries to form a protective film or crust while the underlying material remains soft and plastic. This is an important characteristic because it affords a self-healing effect. When a minor break in the coating occurs,

Table 1. Characteristics of Conventional Storage Preservatives.

	Storage Preservation			
Storage condition and/or severity	Outdoor storage, general exposure to elements	Indoor storage under severe conditions, or outdoor storage (partial shelter) under moderate conditions, or outdoor storage with exposure to elements for short term only	Indoor storage under moderate conditions	Outdoor storage with exposure to elements under the most severe conditions
	A	B	C	D
Product and typical characteristics	Firm coating, resistant to abrasion	Soft coating (self-healing)	Thin oily film	Asphaltic film, needs removal before part is used
Density				
kg/m^3 at 15.6° C	868.5	923.7	876.9	922.5
lb/gal at 60° F	7.25	7.71	7.32	7.70
Viscosity,				
cSt at 40° C	—	—	14	149
cSt at 100° C	24.8	33.1	3.3	—
SSU at 100° F	—	—	79	800
SSU at 210° F	123	162	37.4	—
Flash Point, °C	279	260	166	38
°F	535	500	330	100
Melting or pour point,				
°C	73	66	−4	—
°F	164	151	+25	—
Unworked penetration at 25°C (77°F)	75	245	—	—
Film thickness, mil	1.6	1.6	0.9	3.0
Approximate coverage				
m^2/liter	26	26	44	11
sq ft/gal	1000	1000	1800	450
Non-volatiles, %	99	99	—	55
Methods of application/ temperature, °C	dip/85 brush, swab/60-71	dip/77 swab/18-27	roller coat, brush, mist	spray, dip or brush/ambient
Maximum time until inspection and possible reapplication under condition				
Mild	Extended	Extended	6-12 Months	Extended
Moderate	1-3 Years	1-3 Years	1-6 Months	1-3 Years
Severe	6-12 Months	6-12 Months	Not recommended	6-12 Months

the softer material will slowly flow together and reseal the damaged film. Application of Product "B" is preferably made by dipping at a temperature of 71-77°C (160-170°F). For parts too large to dip, application can be made by brush.

Outdoor Storage—Exposure to the Elements

The degree of protection obtained in exposed outdoor environments will depend to some extent on the thickness and durability of the barrier film provided by the rust preventive material. For relatively short-term storage, Product "B" will give effective protection. For more dependable service over longer periods, Product "A" is recommended. It provides the toughest coating of a product of this type, and is more resistant to film rupture if the part is subjected to rough handling. In the absence of unusual circumstances, Product "A" will provide outdoor protection for a year or more. For dip application, this product should be heated to 85°C (185°F).

For long-term outdoor protection, Product "D" will give the best service. It is a solvent-cutback asphaltic material. The preferred application method is by spray, although dipping and brush applications are also suitable. After application, Product "D" dries to a thick, hard, durable, black film. It must be removed before the part is put in service, although removal is accomplished with a good quality mineral spirits solvent.

Although Products "A" through "C" do not require removal before the part is put in service, care should be taken to be sure that the coating hasn't absorbed abrasive dust.

The representatives of major petroleum companies can usually provide product data sheets which go into greater detail on product characteristics, application procedures, and precautions to be observed with their use. Many of the desirable attributes of premium preservatives can be summarized in general terms. The product should:

- Dry to a mildly tacky film which should not collect appreciable amounts of air-borne particulates.

• Provide freedom from oxidation in indoor and outdoor storage for extended periods of time.
• Due to its polar nature, remove water from the pores of the metal, replacing the water with the rust preventative coating.
• In the form of films, have extremely low moisture transmission charcteristics, even in contact with water.
• Have the ability to neutralize acid, making it a suitable rust preventative for acidic atmospheres and where fingerprints may create a corrosive action on metal surface.
• Be self-healing, if in film form. If the film is accidentally ruptured, it should heal over the ruptured area.
• Even as a film, it should be readily removed with solvent or a solvent-emulsion cleaner when desired.
• Be safe to apply over partially painted or conventional elastomeric parts.

TURBOMACHINERY ROTOR STORAGE AND PRESERVATION

In the petrochemical industry, it is a relatively common practice to have spare rotors available for critically important turbo equipment. The storage and preservation preferences vary and several acceptable methods exist. As is so often the case, each of the various alternatives has its advantages and disadvantages. It is not surprising, then, to find the optimum method for one user and/or geographic location to be different from the optimum method applicable elsewhere.

Rotors placed in storage can be either hung vertically or stored horizontally. Building and crane height limitations may determine whether the space-saving vertical orientation or the more traditional horizontal orientation must be selected. From the standpoint of receiving and preparation, both groups of rotors are handled in an identical manner.

The storage facility should be maintained at a maximum relative humidity of 60 percent regardless of the time of year and geographic location. The storage temperature may range from −40°F (−40°C) to 100°F (38°C) or more. A modern vertical storage facility is shown in Figures 1 and 2.

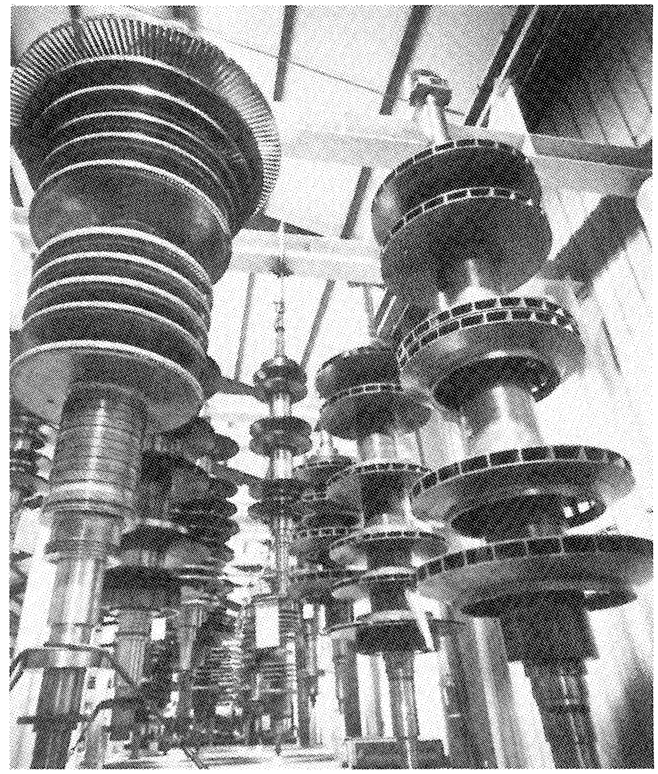

Figure 1. Vertical Rotor Storage. (Source: Hickham Industries, Inc., LaPorte, Texas).

Preparation for Storage

When rotors are received at the storage facility, they should first be stripped of all previously existing preservative. They must also be visually inspected for signs of corrosion, damage, or other problems which might require correction. Following inspection and completion of repairs, the rotor must be coated with a premium quality corrosion inhibitor. A typical product would be based on an inorganic-organic complex. It would be highly polar and would form adherent coatings on ferrous and non-ferrous metals. Application would be by dipping, brushing, or spraying. The type of preservative and application method needed for rotor storage can be selected from Table 1.

A word of caution is in order. Rotors which have been exposed to chlorides, and perhaps certain other corrosive media, must be given a neutralization or inhibitor treatment before the petroleum-based preservative can be applied.

Containerized Rotor Storage

Containerized rotor shipping and storage is extensively used for military jet engines. Adoption of this concept for general turbomachinery rotors followed logically and several user companies have opted for this storage principle. Inert gas type containers for rotors in an ethylene plant are shown in Figure 3. They have been stored outdoors since 1978 or 1979.

A good container is designed for rotor transport and storage with much thought given to handling by cranes and

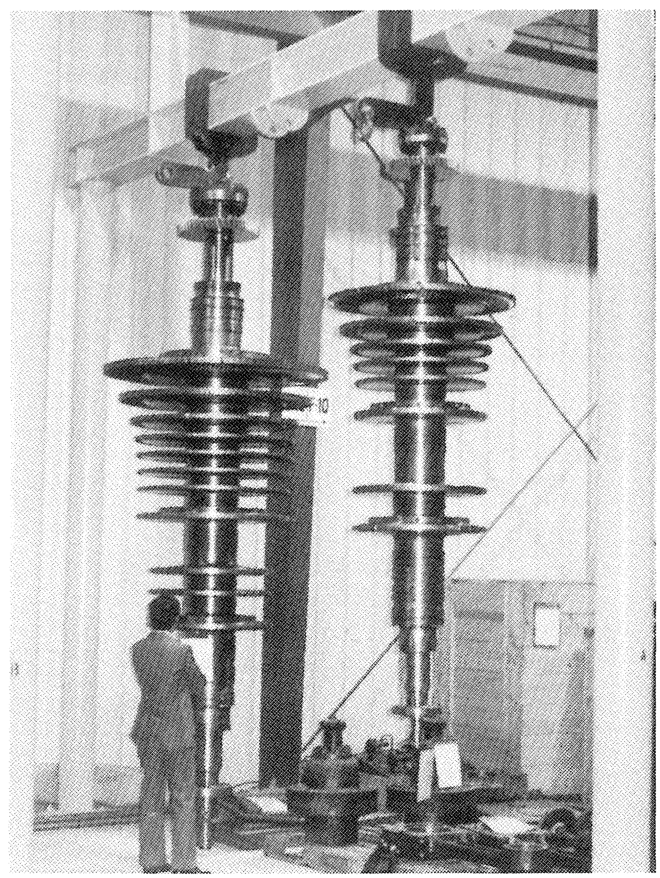

Figure 2. Large Steam Turbine Rotors Vertically Suspended. (Source: Mitsubishi America Ltd., Houston, Texas).

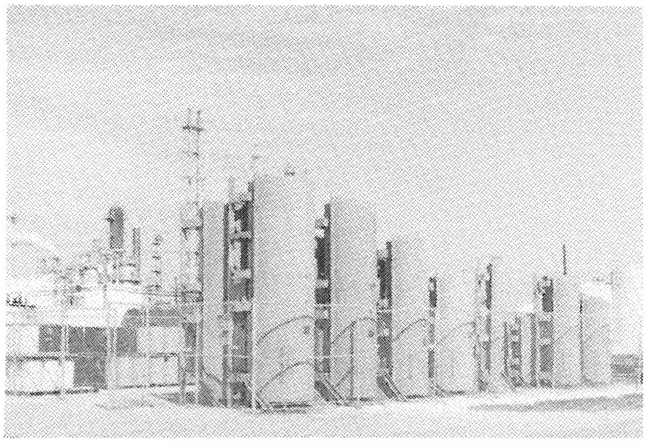

Figure 3. Outdoor Storage of Rotors in Gas-Filled Containers. (Source: Charlie Jackson, Monsanto Company).

forklift trucks. It must be stable enough to resist tipping and rolling in both the vertical and horizontal directions. Containers are stored vertically or horizontally, filled with transformer oil or lube oil, left full of atmospheric air or pressurized with dry nitrogen at pressures ranging from approximately 1 psig to 5 psig (7 kPa to 35 kPa).

Filling with transformer oil or lube oil has occasionally led to difficulties. Certain rotors are assembled with impellers, shaft sleeves or other components that contain undercuts or similarly relieved areas. The oil can penetrate into these areas and cause troublesome unbalance behavior in the rotor once it is recommissioned at a later date. Nevertheless, the problem may not always occur. One user simply applies degreasing fluid under pressure and spins each rotor for 10-20 minutes before considering it safe for installation in the machinery. Also, in applications where any residual oil might react with the process gas at elevated temperatures, the use of inhibited synthetic oils can be considerd as a storage fluid. If a container is filled with air, the metal parts must be coated with a suitable preservative from Table 1. Pressurized dry nitrogen can create an ideal environment for the rotor, especially if supplied from an on-board bottle, and if connected to an alarm system which will announce deviations from acceptable pressure settings.

One such rotor container is illustrated in Figure 4. The container is a fabricated steel weldment, precisely fitted to a given rotor. Standard construction normally consists of an axially split design incorporating a bolted flange with an O-ring seal. The support surface between the element stored and the container is normally a soft material, such as high density neoprene or lead sheet, allowing protection of the bearing surfaces. Polytetrafluoroethylene (PTFE) has occasionally been encountered in the journal support area, but its use is not recommended. There is always the possibility of PTFE constituents entering into the surface layer of the shaft journal. Such permeation could alter the way lube oil coats this critical area during future operation of the rotor.

Similarly, it would not be prudent to allow wood to contact the journal surfaces of a rotor because undesirable interaction between the two materials could occur. A properly designed rotor storage container does not allow contact with the journal area at all.

The container should be tested at assembly to assure pressure retention for extended periods of storage and/or shipment. Following this test, the container should be blast cleaned to bare metal in preparation for coating. The interior should be painted with coatings of zinc rich primer, followed by a thick epoxy-based paint similar to a diesel engine internal crankcase coating. The preferred exterior coating consists of epoxy-zinc-rich primer and top coated with a hi-build epoxy type paint. Hot-dip galvanizing is a suitable alternative coating method.

Rotors have been stored for as long as 12 years before they were put back into use. Evidently, a properly constructed storage container can prove valuable. It typically costs from one percent to about three percent of the price of a rotor.

PRESERVATION OF INACTIVE MACHINERY BY CONVENTIONAL COATING METHODS

The specifics of protecting a given piece of field-installed or stored, assembled machinery can be reasoned out without too much dependence on textbooks, consultants, vendors, manufacturers, and other sources of information. The thrust of this argument is simply stated in the sequential approach outlined below: Identify, Ask, Answer, Implement.

- Identify whether moist air can be trapped in a given machine assembly. If yes, assume the air contains moisture.
- Ask if moisture will cause corrosion or if parts are susceptible to corrosion attack if contacted by water vapors. If yes, how can these water vapors be expelled? (Oil-fill, nitrogen bleed, desiccant load, etc.)

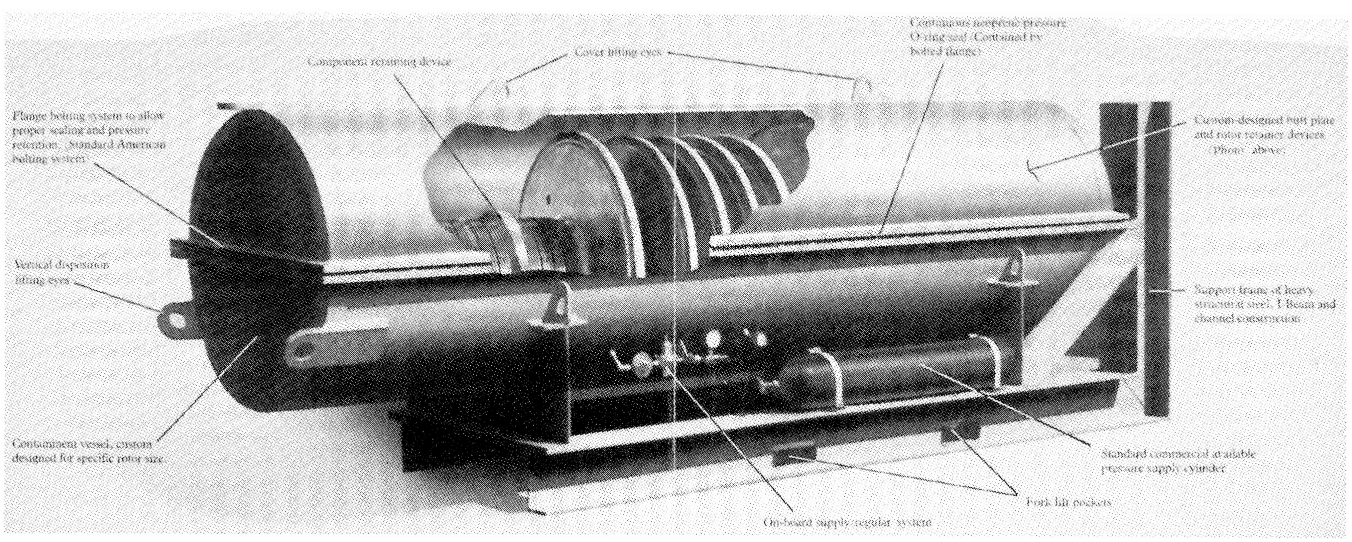

Figure 4. Details of Rotor Storage Container. (Source: Hickham Industries, Inc., LaPorte, Texas).

• Ask what must be done to prevent moisture and/or particulates from again entering into the equipment assembly.

• Implement whatever will accomplish both of these important items. In other words, ways must be found to ensure the expulsion of water vapors and prevent the reintroduction of water and/or solid particles.

Only in the event that the expulsion of vapors and preventing their reintroduction are not achievable would it be necessary to resort to the less elegant technique of applying protective coatings directly to the vulnerable parts.

In essence, two major possibilities are left for the preservation of field-located, inactive machinery: seal an entire cavity, or preserve individual parts only. The first approach requires that the cavity be purged with an inert gas (nitrogen) or oil mist; the second approach requires that a preservative coating or protective skin be applied to the surface of a machine component. Although not preferred for a variety of reasons, the preservative coating or protective skin approach will be dealt with first.

As stated earlier, the effectiveness of a rust preventive depends upon its forming a continuous film in intimate contact with the surfaces to be protected. This effectiveness can be reduced by anything that ruptures this film; consequently, every practical means should be taken to remove dirt, rust, water, corrosive liquids, and other foreign materials from the surfaces to be protected.

Table 1 listed four products which will cover the vast majority of practical applications encountered in the petrochemical industry. Although widely and quite successfully used, care should be taken to prevent undue contact of these preservatives with materials, like rubber and paper, that can be softened or otherwise affected by petroleum-base products.

Basic protection procedures using conventional coating and liquid fill methods are as follows:

Bearings, Oil-Lubricated

Empty the lubricating oil supply (oil cups, bottle oilers, ring-oil reservoirs, etc.) and replace with a small amount of Product "C." If possible, turn the shaft until the preservative oil is distributed to the whole bearing surface. Drain any excess preservative. This procedure applies to both plain and rolling contact bearings.

Bearings, Grease-Lubricated

Product "B" should be applied for both plain and rolling contact bearings, forcing out as much of the old grease as possible. Operation of the bearing to distribute the rust preventative is desirable. Greases used in sealed-for-life anti-friction bearings and in bearings on electric motors are usually long-life products and do not have to be replaced.

Enclosed Gears

As a minimum, the gear oil should be drained and, to the extent possible, all deposits removed. Sufficient Product "C" should be added so that, when the gears are turned, all interior surfaces will be coated with the preservative. Then Product "C" should be drained. The film remaining on the gears will provide the necessary protection.

For superior protection, tape or caulk the areas where shafts protrude through the casing, then fill the gearbox and piping with Product "C" (refer to Figure 5 for caulking details). Plug all vents, but allow space for thermal expansion. Install a valved pipe on the casing. This will serve as a filler pipe for adding oil. Do not drain Product "C" until ready to reactivate the equipment.

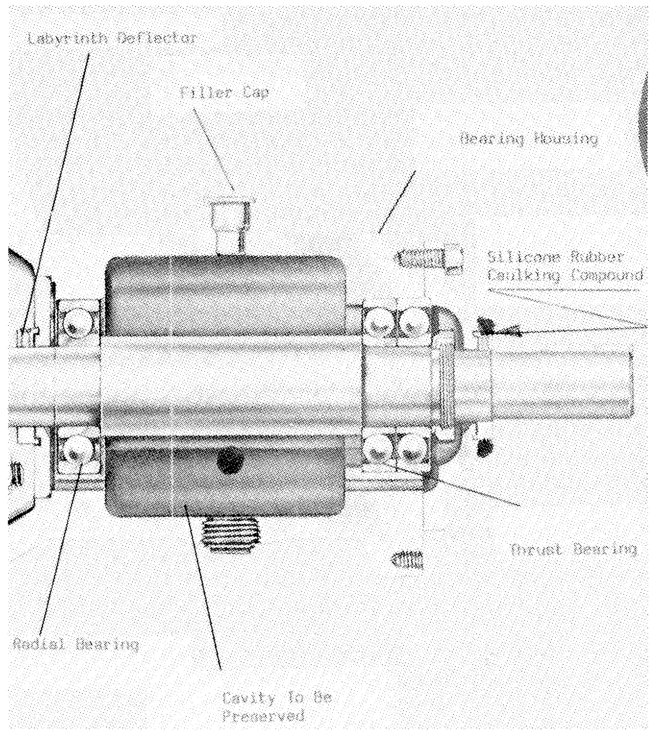

Figure 5. Sealing Compound (Silicone Rubber or Similar) Applied at Shaft Flinger Disk on Centrifugal Pump. (Source: Wilson-Snyder Pumps).

Open Gears, Chains, Sprockets

All exposed surfaces should be coated with Product "A," which should be heated before application.

Flexible Couplings

Drain as much of the lubricant as possible and fill the coupling with Product "B."

Wire Rope

Coat with Product "A." Note the Product "A" must be heated prior to application.

Ways and Sliding Surfaces

Even minute amounts of rust can be disastrous here. The surfaces should be wiped dry of lubricating oil and coated thoroughly with Product "D," which forms a tough black coating that will have to be removed when the equipment is put back in service. However, removal is accomplished by washing with mineral spirits.

Electric Motors and Generators

Small electric motors and generators incorporating standard bearings require conventional bearing protection as indicated under "*Bearings*." For large motors and generators, proceed as follows:

• Blank off the oil return line.
• Seal the shaft openings with black silicone rubber caulking and tape (black caulking will reduce the risk of pilferage).
• Fill the bearing housing with Product "C."
• Install a valved standpipe such that the inlet is higher than the bearing housing.
• Coat all exposed machined parts with Product "A."
• Do not rotate the motor.

Pumps

If possible, the pump suction and discharge should be arranged so that the pump can actually pump a quantity of Product "C," which will coat all internal surfaces. Bearings are treated as outlined previously.

A more specific procedure for centrifugal and rotary pumps would be as follows:

- Flush the pumps and drain the casing.
- A neutralizing step is required on acid or caustic pumps.
- Fresh water flush and air dry all of the cooling jackets.
- Fill the pump casing with Product "C."
- Plug the cooling water jackets, bearings and stuffingbox, but keep the low point drain valve cracked open slightly.
- Apply caulking or sealing compound to areas where the shaft protrudes through the stuffingbox or bearing housing, as shown in Figure 5. Coat the space where the shaft protrudes through the bearing or stuffingbox housings with Product "A," "B" or "D" and cover with tape.
- Coat all of the coupling parts, except elastomers, with Product "A," "B" or "D."
- Fill the bearing housing completely with Product "C."
- Pumps do not require rotation.
- Close the pump suction and discharge block valves.

For *reciprocating pumps,* the procedure is similar:

- Flush and drain the pump casing.
- A neutralizing step is required, if used in caustic or acid service.
- Blind the suction and discharge nozzles of the pump.
- Fill the liquid end with Product "C." Bar over the piston to coat all of the surfaces. Allow some space for thermal expansion.
- Fill the steam end with Product "C." Bar over the piston to coat all of the surfaces.
- Close the inlet and outlet valves.
- Coat all of the joints where the shaft protrudes from the casings with Product "A," "B" or "D." Cover with tape.
- Cover the exposed piston rod, shafts, and machined parts with Product "A," "B" or "D."
- Fill the bearing housing, packing lubricator, and gearbox with Product "C."

Air Compressors

On a reciprocating compressor, drain the crankcase, refill with Product "C," and operate briefly with no load. If possible, spray Product "C" on the interior surfaces of the crankcase. Drain the preservative oil for reuse. For air cylinders and rotary compressors that have mechanical lubricators, drain the oil, refill the lubricator with Product "C" and operate at no load. Other rotary compressors use a circulating oil system: the oil should be drained and replaced with Product "C," and the unit operated at no load for a short period. Afterwards, Product "C" is drained from the system.

Centrifugal Process Compressors

If at all possible, continue to run the lube oil system during periods of idleness. If the system must shut down, proceed as follows:

- Purge the compressor casing of hydrocarbons.
- Flush the internals with solvent to remove heavy polymers.
- Pressurize the casing with nitrogen.
- Mix five percent of an approved rust preventive concentrate with existing lube and seal oil. Circulate this oil through the entire system for one hour, but do not run compressor in either case.
- Blank the oil return header.
- Seal the shaft openings with black silicone rubber caulking and tape.
- Fill the oil console with Product "C."
- Filling should be done when the compressor is at ambient temperature. Turn off all of the heat tracers.
- Coat all of the exposed machined parts, including couplings, with Product "A."
- If possible, keep inert gas (nitrogen) blanketing on the oil console and the compressor casing.
- As an alternative to nitrogen blanketing, consider fogging the compressor internals with Product "C."

Refrigeration Compressors

If Freon® or similar refrigerants are used, the lubricating oil should be left in the system and no other preservative used. An inert atmosphere or refrigerant under very slight pressure should be maintained in the crankcase. For units using ammonia, sulfur dioxide, or hydrocarbons, the refrigerant should be drained and the compressor treated in the same manner as for an air compressor.

Turbines

If possible, keep inert gas (nitrogen) blanketing on the entire casing. If this cannot be done, proceed as follows:

- Isolate the turbine from the steam system. Ensure that there is no chance for steam leakage into the turbine.
- Seal the shaft openings with black silicone rubber caulking and tape.
- Dry out the system with air.
- Fill the turbine casing, including the steam chest, with Product "C." Hold the governor valve open as necessary to ensure the chest is completely full. Vent the casing, as required, to remove trapped air. Fill the trip and throttle valves completely with oil.
- Install a valved pipe on the casing which can serve as a filler pipe for adding oil to fill the casing. Allow space for thermal expansion of the oil in the pipe.
- Coat all of the external machined surfaces, cams, shafts, levers, and valve steams with Product "A," "B" or "D."
- Coat the space between the case and the protrusion of the shaft with Product "A," "B" or "D." Cover space with tape.
- Fill the bearing housings completely with oil.
- Coat the casing bolts with Product "A," "B" or "D."

Large Fans

- Coat the coupling and all external machined surfaces with Product "A," "B" or "D."
- Spray Product "C" on the fan wheel.
- Crack open the casing low point drain valve.
- For bearing preservation, refer to "*Bearings*."

Mixers

Mixers should be filled with Product "C."

Fin Fans

Drive belts should stay on the sheaves. Run for several minutes at least every two weeks.

Internal-Combustion Engines

The following procedure is suitable for the stand-by protection of gas engines or gas-engine-driven compressors:

Drain the water jackets and then circulate Product "C" through the jackets, making sure that all surfaces in the jacket are reached. Drain the system and plug all openings.

On engine lubrication systems, proceed as follows:

• Drain the lubricating oil system, including filters, coolers, governors and mechanical lubricators. Flush the complete system with Product "C." Use an external pump to force this product through the system. Spray the interior of the crankcase thoroughly with Product "C." Do not run or bar-over the engine, because Product "C" has no insufficient viscosity to protect moving parts.

• Refill the mechanical lubricator to the minimum level—just enough to ensure pump suction at all times. Crank the mechanical lubricator by hand until all lines are purged. Where compressors are used, be sure to flood the compressor rod packing.

• Stop and drain the engine sump, filters, coolers, governor, lubricators, etc. Plug all openings.

• Remove the spark plugs or gas injection valves and spray Product "C" inside the cylinders so as to cover all surfaces. While doing this, rotate the engine by hand so that each piston is on bottom dead center when that particular cylinder is being sprayed.

• After this opeation the engine should not be turned or barred over until it is ready to be placed in service. Tag the engine in several prominent places with warning tags.

• Where compressors are involved, including scavenging air compressors, remove the valves and spray inside the cylinder to cover all surfaces. Dip the compressor valves in Product "C" and drain off the excess. Reassemble the valves in place.

Hydraulic Systems

Drain the system and refill with a sufficient quantity of Product "C" to be circulated to all parts of the system when the hydraulic or circulating pump is operated. Valves and other units within the hydraulic system should be actuated to assure full contact with the preservative oil. After a sufficient period of operation, Product "C" can be drained from the system.

Lube and Seal Oil Systems

It is sometimes economical to leave lube and seal oil systems in service, even though the machinery train is shut down for extended periods of time. However, during this operating period, special care must be taken to keep the reservoir free of water. Water collects because the system will "breathe" and expel oil vapors through shaft seal areas and reservoir vents as the ambient temperature rises. If the ambient temperature drops, the vapors within the system will contract and allow moisture-laden atmospheric air to enter. Moisture condensation may result and cause corrosion damage.

If shut down, large lube and seal oil reservoirs can be protected by adding an approved rust preventive compound. Typically, the procedure would be as follows:

• Add five percent rust preventive concentrate to the lube and seal oils.

• Circulate this oil throughout the piping system. Open and close control and bypass valves so that all piping and components will receive oil circulation and become coated. Circulate the oil for one hour. Vent trapped air from all components and high points.

• Block in filters and coolers. Fill these items completely with oil containing five percent rust preventive concentrate, but allow a small space for thermal expansion. The water side of coolers should be drained and air dried. Plug all vents. Lock the drain connections in a slightly open position.

• Top off the reservoir with oil containing five percent rust preventive concentrate. Blind or plug all connections to the tank including the vent stack.

• Coat the exposed shaft surfaces and the couplings of oil pumps with Products "A" or "B."

Reciprocating Compressors

• Purge the compressor cylinders of hydrocarbons.

• Blank the compressor suction and discharge.

• Refer to remaining applicable guidelines under *Internal Combustion Engines*.

Unpainted Exterior Surfaces

Product "A" (heated) should be applied to all exterior surfaces, both finished and unfinished. Where especially good protection is required for finished surfaces, Product "D" should be used.

Protected Units Should Be Clearly Identified

In most cases, protection will have involved draining the lubricant or replacing it with a preservative. Such equipment should be tagged with a warning that the proper lubricant must be replenished before the unit is operated.

Health Precautions Are Important

Health studies have shown that many petroleum-base products pose potential human health risks that may vary from person to person. As a precaution:

• exposure to liquids and vapors of petroleum products should be minimized.

• if long-term contact is unavoidable, wear chemical-resistant gloves and an apron.

• preservative products and lubricants should be promptly removed from the skin by the liberal use of water and soap.

• soiled clothing should not remain in contact with the skin.

• protective goggles should be worn when applying preservative products.

• a respirator should be used in spray applications.

• if soiled by preservatives or lubricants, shoes should be thoroughly cleaned; if soaked, they should be discarded.

• the manufacturer's or supplier's Material Safety Data sheet should be carefully reviewed and its recommendations should be followed.

PRESERVATION BY NITROGEN PURGE OR OIL MIST APPLICATION

Machinery preservation during pre-erection storage or long-term deactivation (mothballing) will have an effect on machinery infant mortality at the startup of a plant or process unit. Many times, machinery arrives at the plant site long before it is ready to be installed at its permanent location. Unless the equipment is properly preserved, scheduled commissioning dates may be jeopardized, or the risk of failure is increased.

Long-term storage preservation by nitrogen purging is well known in the industry. Generally, this method of excluding moisture is used for small components, such as hydraulic governors or large components, such as turbomachinery rotors kept in metal containers, as illustrated in Figure 4. Nitrogen consumption is governed by the rate of outward leakage of this inert gas and may be kept at a low, highly economical rate if the container is tightly sealed. The container needs to be pressurized to only about 10 in (2.5 kPa) of water column, although a more typical rate is approximately 1 psig to 5 psig (7 kPa to 35 kPa). It may be fitted with a safety relief valve to prevent overpressures. Alternatively, the container could be furnished with an orificed vent to promote through-flow of nitrogen at very low pressure. This is called nitrogen sweep.

However, the preservation of field-installed inactive machinery is the primary concern. Here, purging can be applied in one of two ways: as pure nitrogen purge, which would be expensive, or by applying an oil mist which would be more cost-effective. Oil mist preservation is shown in Figures 6 through 12. This highly advantageous preservation method consists of a centralized system which utilizes the energy of compressed air to supply a continuous feed of atomized rust preventive or lubricating oil to multiple points through a low pressure distribution system at approximately 5 kPa or 20 in of water pressure. The volumetric ratio of air to lube oil is roughly 200,000:1. After leaving the header system, the oil mist passes through a small diameter nozzle before entering the cavity to be preserved. This nozzle, or application fitting, meters the oil mist stream so that the cavity or housing is pressurized to less than 0.5 in of water (less than 125 Pa pressure). The oil mist generation principle is illustrated in schematic form in Figure 13.

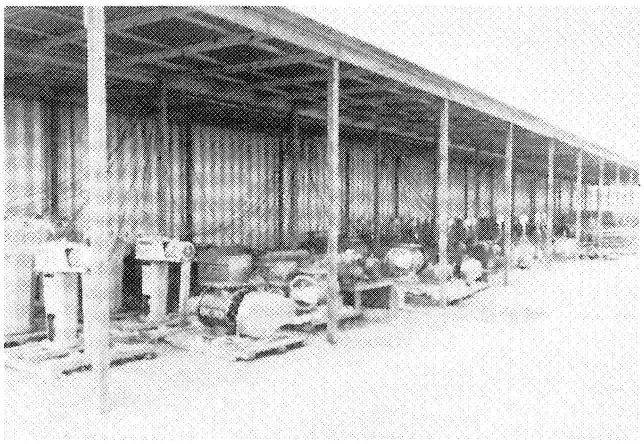

Figure 6. Covered Outdoor Storage with Oil Mist Application. (Source: Lubrication Systems Company, Houston, Texas).

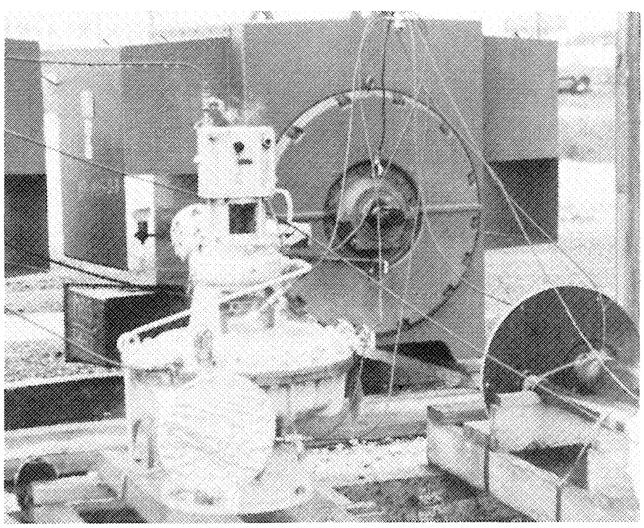

Figure 7. Oil Mist Preservation of Steam Turbine and Large Motor in West Outdoor Environment. (Source: Lubrication Systems Company, Houston, Texas).

When used as a storage preservation medium, oil mist can be made to enter the cavity (e.g. bearing housing, seal housing, trip valve mechanism, coupling enclosure, machinery casing, etc.) at any convenient location other than the bottom drain. This mist will typically exist at a pressure of approximately 0.5 to 1 in of water (125-250 Pa) and will migrate toward the surrounding atmosphere. In essence, it performs two

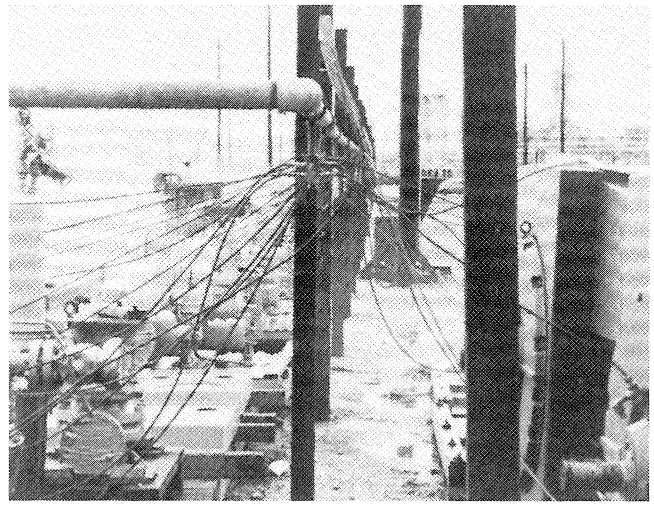

Figure 8. Outdoor Storage Yard Using Oil Mist Preservation. (Source: Lubrication Systems Company, Houston, Texas).

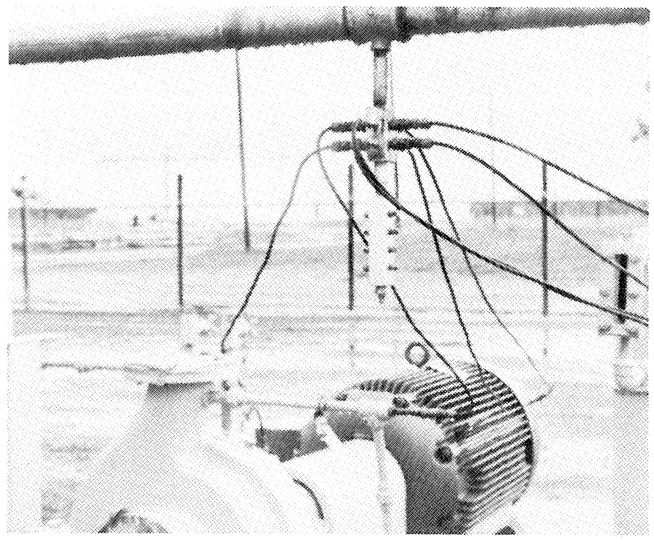

Figure 9. Outdoor Storage Preservation Detail Showing Oil Mist Header and Distribution Block. (Source: Lubrication Systems Company, Houston, Texas).

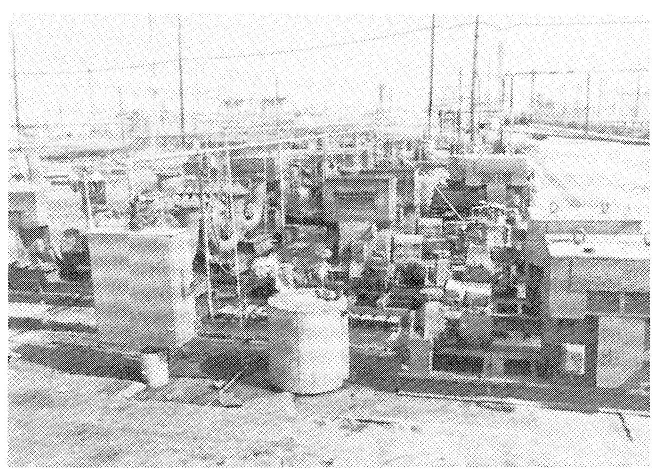

Figure 10. Outdoor Storage Yard with Oil Mist Console and Large Lube Oil Supply Tank in Foreground. (Source: U.S. Gulf Coast Refinery).

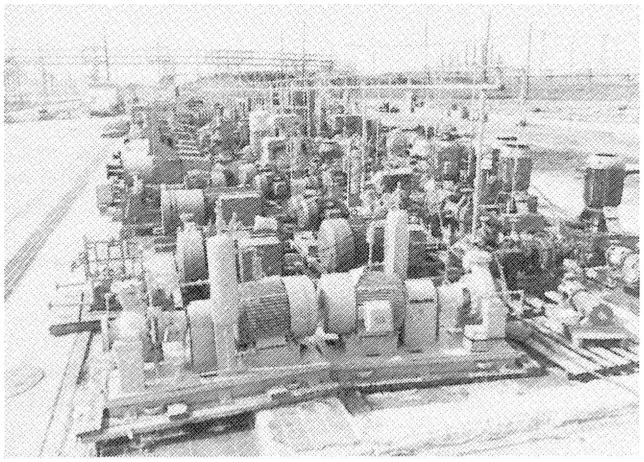

Figure 11. Oil Mist Preservation Storage Yard Overview. (Source: U.S. Gulf Coast Refinery).

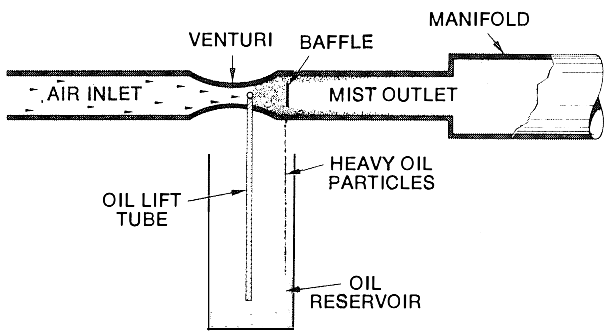

Figure 12. Principle of Oil Mist Generation. (Source: Alemite Division of Stewart-Warner Corporation, Chicago, Illinois).

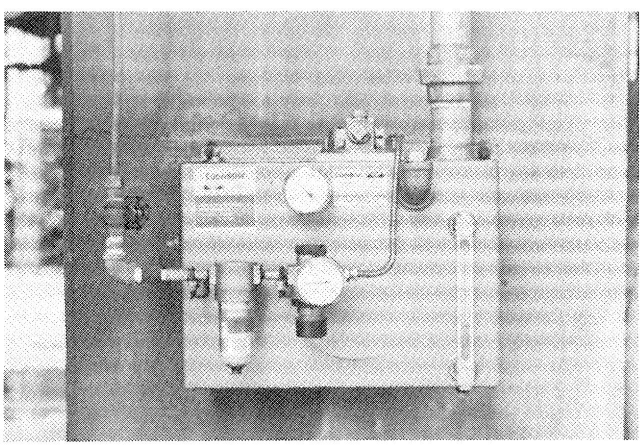

Figure 13. Small Capacity Combined Oil Reservoir-Mist Generator Module. (Source: Alemite Division of Stewart-Warner Corporation, Chicago, Illinois).

equally important functions: it prevents the ingress of atmospheric air which might contain moisture and airborne contaminants, and it coats the machinery components with a corrosion-inhibited premium lubricant.

Storage preservation using oil mist methods is used outdoors and under protective shelters. Machinery storage yards in petrochemical plants in the U.S. Gulf Coast area are depicted in Figures 6, 7, 8, 9, 10 and 11.

Oil mist storage preservation systems are bare-bones oil mist lubrication systems. Virtually no electric controls or supervisory instrumentation are needed since a temporary outage would be of no serious consequence. Typical combined reservoir-control modules are illustrated in Figures 13 and 14. Although both of these combination modules have generally been used in outdoor storage yards, they have recently found a new field of application in the preservation or mothballing of major turbomachinery trains, which had to be decommissioned for an indefinite time period. If major machinery is to be dependably preserved and yet kept ready to be returned to service without undue loss of time, oil mist preservation merits serious consideration.

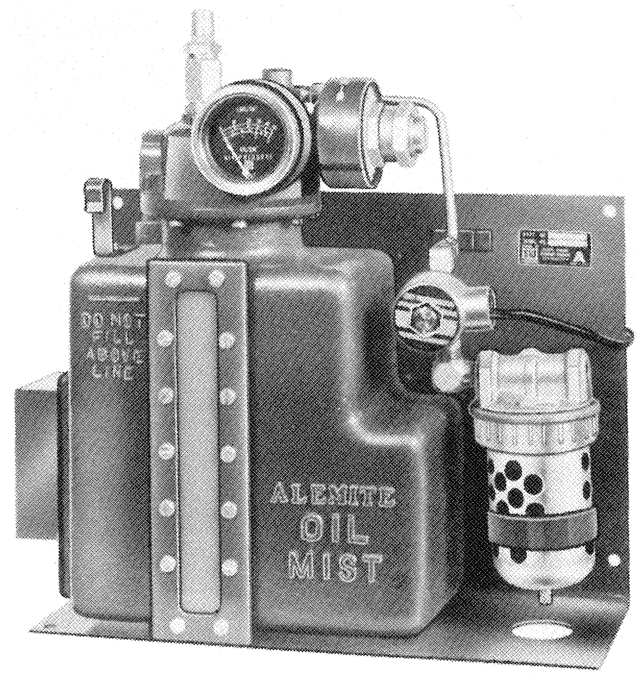

Figure 14. Medium Capacity Combined Oil Reservoir-Mist Generator Module. (Source: Alemite Division of Stewart-Warner Corporation, Chicago, Illinois).

Major machinery in an ethylene plant which is being preserved in this manner is illustrated in Figures 15, 16 and 17. Oil mist headers run the length of the platform. Lateral pipes branch out from the header and distribution blocks form the pipe terminus. Stainless steel or plastic instrument tubing connects the distribution block with the small oil mist application fitting at the point to be preserved.

While application fittings for operating equipment must be sized to provide sufficient lube oil to satisfy a given bearing size or configuration, the sizing of the application fittings for preservation systems can safely be left to cursory estimate. As a matter of practical experience, bearing housings, governors, valve mechanisms, etc., are usually served by fittings with a bore diameter of 0.047 in (1.2 mm) and only on the largest casings of steam turbines, gears, etc., would larger fittings, with a bore diameter of 0.060 in (1.5 mm), be used. At a header pressure of 20 in (approximately 5 kPa), the smaller application fitting delivers 0.18 cfm (0.3 m^3/hr) and the larger 0.30 cfm (0.5m^3/hr) of mist to the cavity to be preserved.

Mist Oil Requirements

To be suitable as a mist lubricant, an oil must be formulated such that stray misting (i.e., the escape of mist beyond

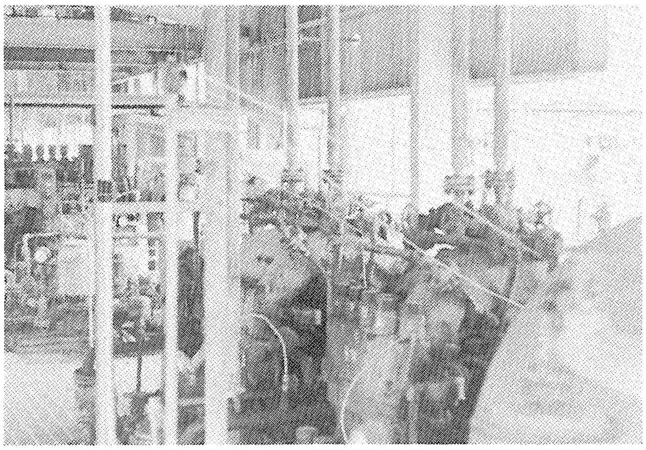

Figure 15. Major Machinery Temporarily Deactivated and Preserved with Oil Mist. (Source: Phillips Petroleum Company, Sweeny, Texas).

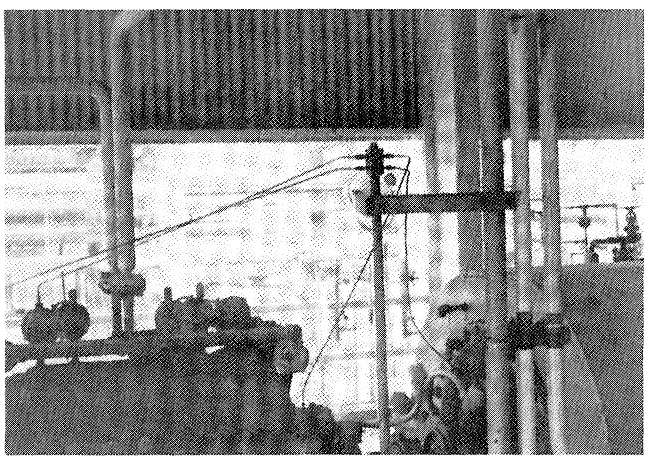

Figure 16. Vertical Pipe and Distribution Block Supplying Oil Mist to Mothballed Compressors. (Source: Phillips Petroleum Company, Sweeny, Texas).

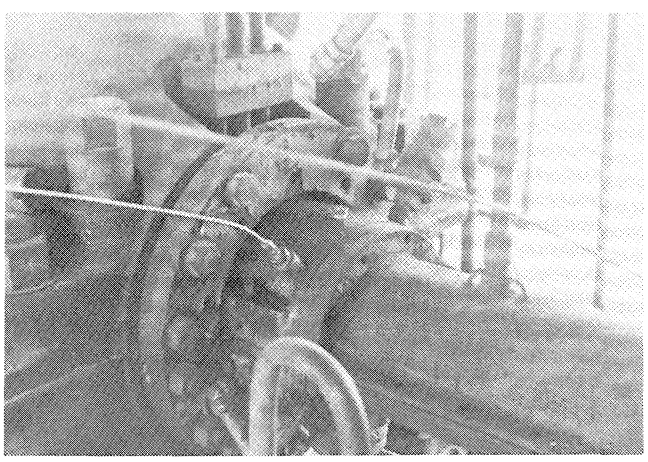

Figure 17. Oil Mist Preserving Turbomachinery Coupling. (Source: Phillips Petroleum Company, Sweeny, Texas).

the point of application) is minimized. The additives used in specially formulated oil mist lubricants to suppress stray mist do so by reducing the number of oil particles that are too small to be condensed, or reclassified, at the point of application. For a typical specification of premium grade oil, refer to Table 2.

Table 2. Premium Grade Oil Mist Lubricant Data.

Physical Properties	Viscosity cSt 40°C	100°C	VI	Pour °C	Flash, COC °C	Density @ 15°C kg/m^3
Grade 100	100	9.2	56	−30	196	919
Grade 150	150	14.1	100	−9	216	893
Grade 220	220	18.1	98	−6	230	899
Grade 320	320	23.1	96	−6	230	911
Grade 460	460	29.1	92	−9	224	917

Occasionally a user may elect to use premium grade oil mist lubricants, opting instead for a naphthenic base lubricant as a preservative oil. Since naphtha-basestock reduces the probability of wax plugging of small application fittings, it is important that these lubricants be specified instead of oils containing a paraffinic base.

Finally, diester-base synthetic lubricants could be used in the oil mist preservation systems. These lubricants are especially suited for low temperature storage conditions because they do not contain wax-forming constituents. Refer to Table 3 for physical data.

Table 3. Characteristics of Diester-Base Synthetic Lubricant for Oil Mist Preservation Systems (Source: Exxon Company, U.S.A. Commercial Bulletin).

Physical Properties	Viscosity cSt 40°C	100°C	VI	Pour °C	Flash, COC °C	Density @ 15°C kg/m^3
Syn 32	30.1	5.6	120	−57	246	917
Syn 68	65.0	7.5	70	−33	266	955
Syn 100	95.0	10.1	85	−48	246	961

Determination of Oil and Air Consumption

Figure 18 can be used to determine the rate of oil and air consumptions. A system comprised of 100 large or 167 small application fittings would consume 30 cfm (50 m^3/hr) of oil mist. Since a suitable volume ratio of air to oil would be

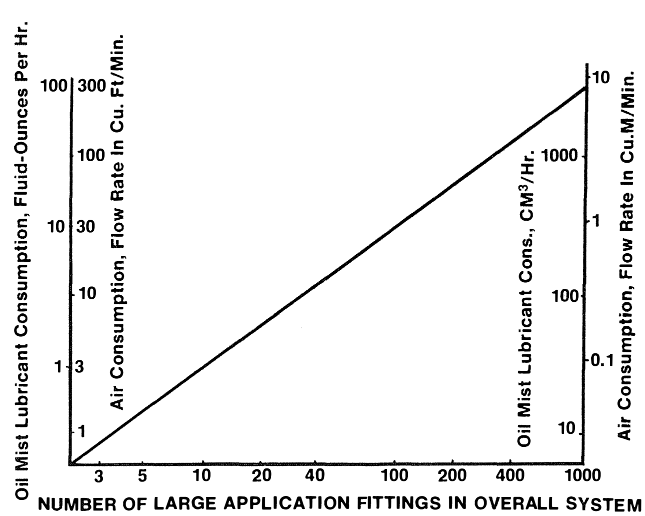

Fig. 18: Oil Mist Lubricant And Air Consumption Of Oil Mist Preservation System

Figure 18. Consumption of Lube Oil and Air as a Function of System Size. (Source: Bloch, H. P.; Improving Machinery Reliability, *Gulf Publishing Company, Houston, Texas, 1982).*

200,000:1, this particular installation would consume approximately 250 cm^3, or 8.5 fluid ounces, of lube oil per hour. In one year, the system would use about 580 gallons (2200 liters) of lube oil.

Based on 1985 cost data in the United States, approximately \$3 per one gallon (3.8 liters) of lube oil and \$0.40 for 1000 ft^3 (\$0.014 per m^3) of air will be expended. Motive air consumed would thus be estimated at \$6600 per year. This figure would include equipment maintenance, power, depreciation, etc.

Cost of Oil Mist Preservation

The cost of implementing and operating an oil mist preservation system must be weighted against the probable cost of having to repair or recondition unprotected machinery. Here are some figures:

• A 24-point oil mist preservation system incorporating the generator-reservoir module shown in Figure 13 was installed on an integral gas engine-reciprocating compressor for \$3500. Application points included six power cylinders, six compressor cylinders, the crankcase, and the distance piece housings.

• The storage yard preservation system shown in Figure 6 included approximately 400 ft (125 m) of header pipe and plastic tubing runs to over 400 points of application. It was installed and commissioned for not quite \$10,000, exclusive of the air compressor.

• A special skid package (Figure 19) was assembled for a South American refining complex. This totally self-contained system cost \$21,000 and was initially used for storage protection. It should also serve as an emergency backup unit for plant-wide oil mist lubrication systems, or could be used for long-term preservation of installed, but temporarily deactivated machinery trains.

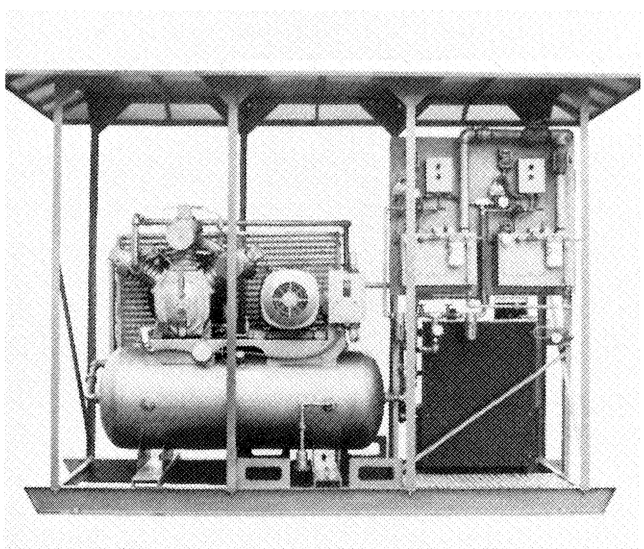

Figure 19. Skid-Mounted Oil Mist Preservation System. (Source: Lubrication Systems Company, Houston, Texas).

Reactivation of Machinery

Oil mist preservation is ideal for machinery which is to be reactivated or restarted on short notice. If the recommissioning crew is familiar with the machinery, crew members can be instructed to implement one of three steps prior to normal restart:

• Drain excess lube oil from cavities normally filled with the same lubricant as was used in the oil mist preservation unit.

• Drain the oil mist lubricant from cavities which require a different lubricant, then refill with the correct lubricant.

• Drain any oil mist luricant which may have condensed in cavities not normally requiring the presence of lube oil, then plug the cavity.

In cases where personnel are unfamiliar with the machinery to be reactivated, each application point should be tagged with a brief description of one of the three prerequisite steps listed above. Removal of oil mist reclassifier fittings and plugging or capping comprise the final step prior to equipment restart. The entire reactivation procedure may take as little as one man-hour on a large pump, and three man-hours on a turbomachinery train consisting of driver, transmission gear, and driven machine.

CONCLUSION

With the escalating cost of downtime and machinery repairs, proper storage preservation and machinery mothballing techniques are becoming more important. In the vast majority of cases, a conscientiously executed preservation program will pay for itself very rapidly. In some instances, the avoidance of a single pump repair event due to proper equipment preservation can pay for an entire preservation program! It is hoped that the reader will benefit from these experiences and the guidelines set forth.